

# EFFECTS OF HABITAT DEGRADATION ON BIOLOGICAL ENDPOINTS IN THE SOUTH FORK BROAD RIVER BASIN, GEORGIA

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**Abstract.** The effects of habitat degradation on biological endpoints were studied at 13 sites in and adjacent to the South Fork Broad river basin. Constrained ordination was used to relate benthic macroinvertebrate and fish data to habitat and environmental data. Benthic macroinvertebrates were primarily influenced by habitat, while fish were affected by stream order and secondarily by habitat. Habitat degradation was related to: a decrease in stoneflies, caddisflies, and the Clingers/Burrowers ratio; a decline in the abundance of darters and suckers; and an increase in the number of sunfish species.

## INTRODUCTION

Many streams of the Piedmont ecoregion in Georgia have been negatively impacted by human activity in the watershed. In the Savannah river basin, the Georgia Dept. of Natural Resources has listed 15 streams that are not supporting their designated uses because of nonpoint source pollution. Nonpoint source pollutants adversely affect flow, aesthetics, and animal habitat.

EPA's Office of Research and Development has established a research program on one of these Savannah river basin watersheds, the South Fork Broad, to develop technology to establish water quality controls for impaired streams. The project includes field monitoring of biotic endpoints (benthic invertebrates and fish) and environmental data (habitat and physico-chemical data). Biotic endpoints are important indicators of habitat degradation resulting from nonpoint source pollution (Karr and Chu, 1999).

Here, biotic endpoints are related to environmental data from the South Fork Broad river to determine: 1) how important habitat degradation is, relative to other variables, in explaining differences among sites, and 2) what changes in biotic endpoints result from habitat degradation. Results can support establishment of quality controls for Georgia's impaired waters by quantifying mechanisms by which nonpoint pollution affects biota.

## METHODS

This analysis uses data collected at 13 sites in and adjacent to the South Fork Broad river basin, a tributary of the Savannah River located in northeast Georgia, in July 1999 (Figure 1). Benthic invertebrate, fish, and environmental data were taken from Pruitt and Howard (2000). Data collection methods are described in Pruitt and Howard (2000). They used a multihabitat approach to sample benthic invertebrates. Habitats sampled were riffles, leaf packs, undercut banks, woody debris, and pools. Benthic invertebrate data were summed across habitats to obtain one abundance value per taxa per site. Fish were collected by electrofishing at all major habitat types in proportion to their occurrence. Fish abundance data was adjusted for analysis by dropping species occurring at less than two sites.

Pruitt and Howard (2000) provided data on pH, conductivity, temperature, dissolved oxygen (DO), and two habitat indices, Pfankuch, and Rapid Bioassessment Protocol (RBP). Stream order was assigned based on 1:24,000 scale topographic maps. The environmental data set was subjected to three analyses. Spearman rank correlations verified that none of the variables were significantly correlated ( $r > 0.9$ ). Univariate analysis showed that only pH was non-normally distributed. Factor Analysis showed that DO had low explanatory power compared to the other variables. Variables pH and DO were dropped, and the remaining variables were used in further analysis.

Constrained ordination was used to relate biotic endpoints to environmental variables. This technique ordinated sites and species simultaneously by arraying them in multivariate space, while constraining the axes to be linear combinations of the environmental variables. Redundancy analysis (RDA), which assumes a linear response of taxa to axes, was used for benthic invertebrates; Canonical Correspondence Analysis (CCA), which assumes a unimodal response of species to axes, was used for fish (Ter Braak, 1988).

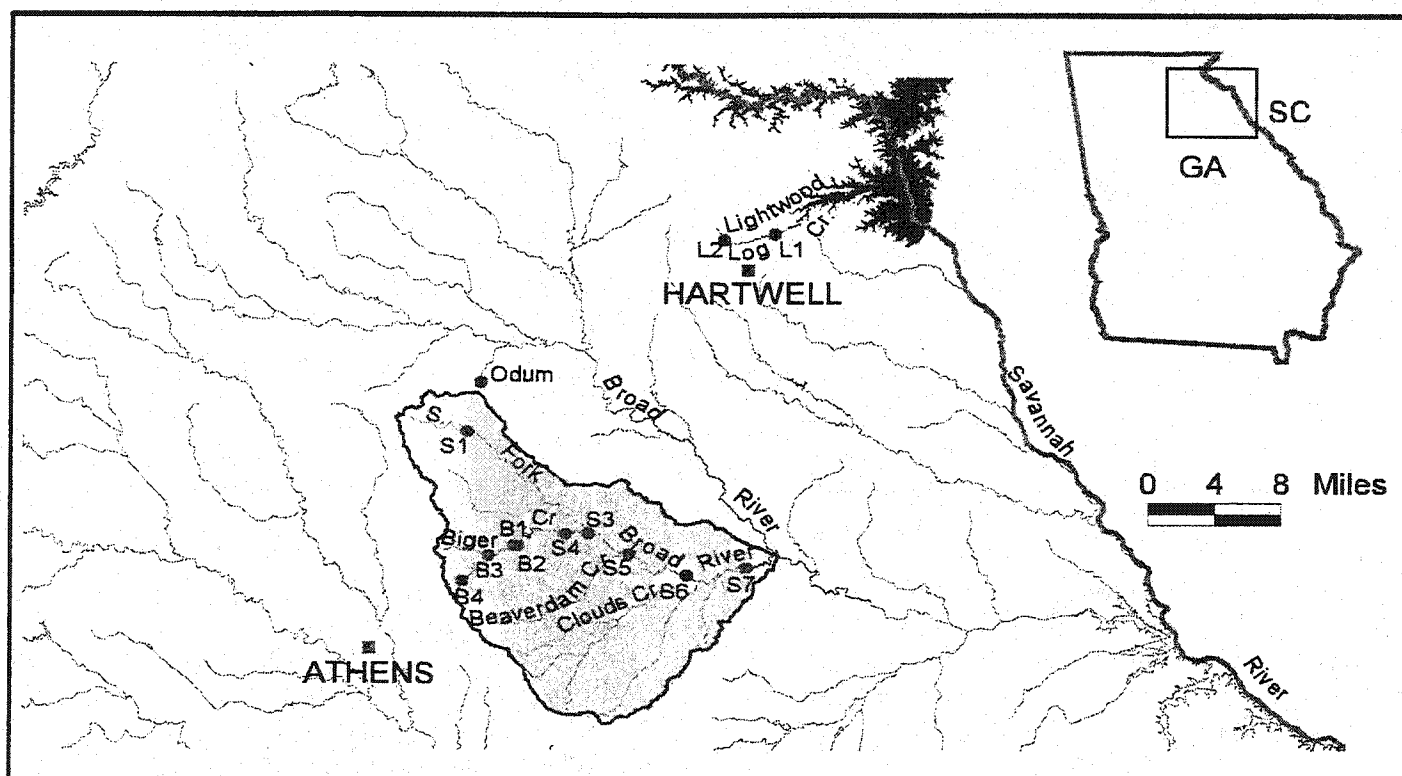


Figure 1. Location of the sampling sites used in this study. Sites outside the South Fork Broad Watershed are used as reference conditions.

Metrics (measurable aspects of the biological assemblages) were then correlated with ordination axes. All metrics from Pruitt and Howard (2000) were used except: benthic invertebrate clinger/burrow ratio in riffles, which was undefined for some sites; number of non-native fish species, which was zero for all sites; and Brillouin fish diversity index, which was highly skewed. Spearman correlations between the remaining nine metrics for each taxa (Table 1) and ordination axes site scores were considered significant at  $p < 0.05$ .

## RESULTS

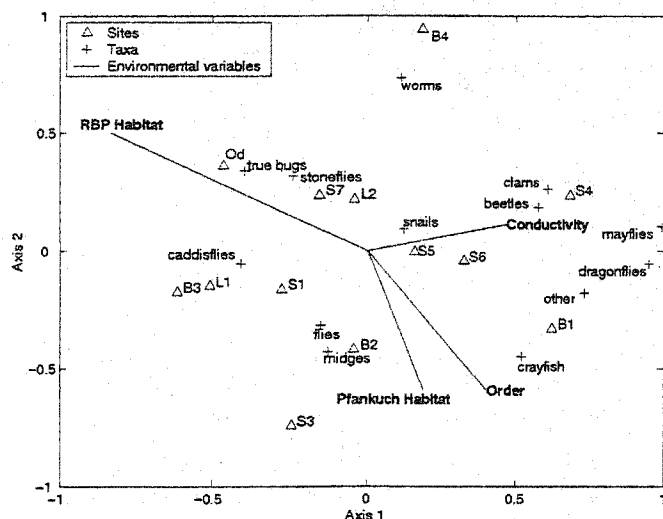
Results from constrained ordination are shown as triplots (Figures 2,3) where sites, taxa/species, and environmental variables are plotted simultaneously in a space defined by the first two ordination axes. Taxa/species locations in the triplot approximate their peak abundances relative to the axes. Sites are plotted based on their taxa/species composition. Sites in close proximity are more similar in their taxa/species composition.

Table 1. Biological metrics used in analysis

Benthic invertebrates	Fish
# individuals	# species
# clingers	# native sucker
% clingers	# native sunfish
# burrowers	# minnow
% burrowers	# darter
clingers/burrowers	% omnivores
EPT index	% benthic insectivores
% Diptera	# lithophils
% dominant taxon	% lithophils

### Benthic Invertebrates

The RDA ordination results for benthic invertebrates are given in Figure 2. The first axis (horizontal) explained 38.2% of the variance in taxa data. Environmental variables most highly correlated with Axis 1 were RBP habitat ( $r = -0.80$ ) and Conductivity ( $r = 0.45$ ). The first axis separated sites with high-quality habitat (high RBP and low Pfankuch habitat scores) on the left of the diagram from poorer quality sites at the right of the diagram. High quality sites include lower-order sites (S1 and B3), reference sites (Odum, L1, L3), and the most downstream South Fork Broad site (S7).



**Figure 2.** RDA results for benthic invertebrates abundance by taxa. The importance of each environmental variable is indicated by its length and its association with each axis is indicated by acuteness of the angle to the axis.

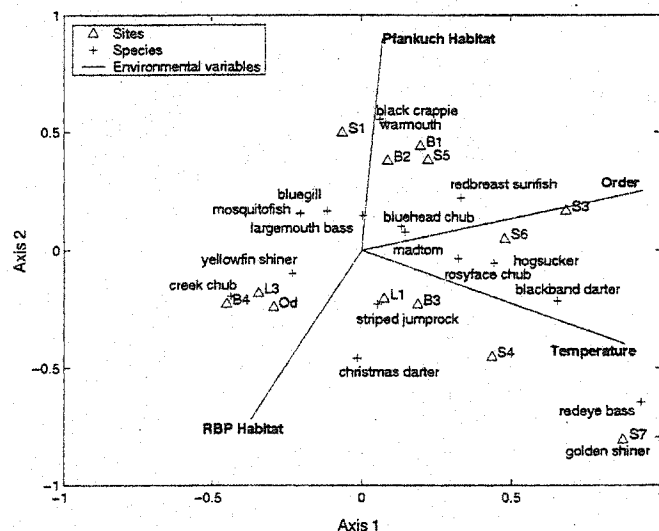
High abundances of stoneflies, caddisflies, and true bugs characterized sites with good-quality habitat at the left of Figure 2. The highest abundances of mayflies and dragonflies occurred at the right end of Axis 1. Four metrics (number of individuals, number of clingers, % burrowers, and Clingers/Burrowers ratio) all declined along Axis 1 with habitat degradation.

The second RDA axis (vertical) explained 6.7% of the variance in species data. Variables most highly correlated with Axis 2 were Pfankuch habitat ( $r = -0.44$ ) and Stream Order ( $r = -0.44$ ). The second axis largely separated site B4, a low-order Biger Creek tributary with a high abundance of worms, from the other sites. No metrics were significantly correlated with Axis 2.

### Fish

The CCA ordination results for fish are given in Figure 3. The first axis (horizontal) explained 24.8% of the variance in species data. Environmental variables most highly correlated with Axis 1 were Stream Order ( $r = 0.88$ ) and Temperature ( $r = 0.83$ ). Headwater sites S1, B4, and Odum grouped together closely at the left of the diagram. High-order streams plotted on the right of the diagram, including S3 and S7 on the mainstem South Fork Broad, and S4 and S6, located at the mouths of the larger tributaries Brush and Clouds Creeks, respectively.

Lower-order sites were dominated by two minnow species, creek chub and yellowfin shiner. Two metrics



**Figure 3.** CCA results for fish relative abundance (see Fig. 2 for explanation).

(number of darters and % benthic insectivores) were significantly and positively related to Axis 1. Benthic insectivores characterizing the high-order streams included blackbanded darter and hogsucker.

The second axis (vertical) explained 10.4% of the variance in species data. The environmental variables Pfankuch habitat ( $r = 0.76$ ) and RBP habitat ( $r = -0.60$ ) were most highly correlated with Axis 2. High quality sites, with high RBP and low Pfankuch scores, plotted at the bottom of the diagram. In contrast, sites on lower Biger Creek (B1 and B2), Beaverdam Creek (S5) and upper South Fork Broad (S1) plotted at the top of Figure 3, indicating that they have poorer habitat.

Along Axis 2, habitat degradation is characterized by declining abundance of darters and suckers (hogsucker and jumrock), a shift in piscivores (from redeye bass to crappie and warmouth), and an increase in sunfish (bluegill, warmouth, redbreast sunfish). One metric, number of sunfish species, was significantly and positively correlated with Axis 2.

### DISCUSSION

Biotic endpoints in the South Fork Broad River basin are influenced by both natural and human factors. Benthic invertebrates were more influenced by habitat degradation than fishes, supporting Berkman et al.'s (1986) finding that fish response is more indirect and complex. Fish were most strongly influenced by stream order, and secondly by habitat. Fish assemblage

changes that occurred in response to stream order are typical for the Piedmont (Schleiger, 2000). The influence of stream order must be factored out when using fish to assess water quality.

Both the RBP and Pfankuch habitat measures were useful in explaining differences in biotic endpoints among sites. The RBP habitat measure was better for invertebrates, while the Pfankuch habitat measure was stronger for fishes. Further analysis of the differences in these measures can help identify the specific habitat factors to which different biotic endpoints respond.

For benthic invertebrates, habitat degradation led to declines in the abundance of caddis- and stoneflies. These are recognized as the two most sensitive taxa in the southeast (Lenat, 1993). Surprisingly, mayflies, the third most sensitive taxa (Lenat, 1993), did not show sensitivity to habitat and instead may be affected by conductivity.

Habitat degradation was also related to a decline in clingers (taxa adapted for attachment to surfaces), a change expected with degradation (Barbour et al, 1999). Decline of clingers and the clinger/burrower ratio is related to sedimentation and filling of pools in the South Fork Broad (Pruitt and Howard, 2000).

For fish, habitat degradation appears to reduce the abundance of darters and suckers. This pattern was not measured by the metrics, which count species number and not abundance. Since species numbers were low in these streams (a maximum of two species of both darters and suckers), abundance may be a better measure. A decline in darters and suckers in response to degradation is expected (Shaner, 1999). Their decline indicates degradation of the benthic habitat, which is consistent with the declines observed in benthic invertebrates.

Increase in the number of sunfish metric with degradation is unexpected (Shaner, 1999). However, an increase in the proportion of sunfish individuals with degradation has been observed elsewhere in the Piedmont (Ga. DNR, pers. comm). This pattern may reflect release from competition with other insectivores, nutrient enrichment, or the high tolerance of sunfish.

Habitat degradation resulting from nonpoint source pollution negatively impacts biota in the South Fork Broad river basin. Biological endpoints are useful indicators of this degradation because they integrate the effects of multiple stressors over time. Findings from this study will be combined with physical and chemical water quality criteria in EPA's ongoing project in the South Fork Broad with the long-term goal of establishing comprehensive quality controls for Georgia's impaired waters.

## ACKNOWLEDGMENTS

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